ULTRACAPACITORS

BUS APPLICATION BRIEF

REVOLUTIONIZING HOW THE WORLD MOVES PEOPLE.

Carbon emissions, the depletion of natural resources, traffic congestion and the rising costs of fossil fuels are all issues pushing the world to search for alternative means of transportation. Mass-transit buses, fleet vehicles, trains and heavy-transportation vehicles all benefit from the adoption of a hybrid power train approach with the use of ultracapacitors.

Ultracapacitors quickly capture energy from braking and then use that energy to provide a short burst of power during acceleration to dramatically reduce the use of fuel in a conventional internal combustion engine or battery drain in an electric/hybrid system. Maxwell ultracapacitors are compact, high-performance, have exceptionally long-life and fulfill many of the functions of batteries but with dramatically higher reliability and are virtually impervious to any climate condition.

Ultracapacitors:

- Breakthrough energy storage and delivery devices

Ideal for:

- Regenerative braking systems
- Start-stop systems
- Cold climate starting
- Hybrid electric vehicles:
  - Buses, trains, trolleys, light rail

Green technology:

- High efficiency with fewer CO_2 emissions
- Lead free

Used in over 4,000 buses worldwide:

- MAN
- Gillig
- New Flyer
- NYC Hybrid
- BAE Bus

Maxwell® TECHNOLOGIES

Enabling Energy's Future™

ULTRACAPACITORS

BUS APPLICATION BRIEF

Specifications

	K2 Series	48 V Modules	125 V Modules
Capacitance	650 - 3,000 F	83 - 165 F	63 F
Voltage	2.70 V	48 V	125 V
ESR, DC	0.29 - 0.8 mohm	6.3 - 10 mohm	18 mohm
Leakage Current	1.5 - 5.2 mA	3.0 - 5.2 mA	10 mA
E_{max}	4.1 - 6.0 Wh/kg	2.6 - 3.9 Wh/kg	2.3 Wh/kg
P_{max}	12,000 - 14,000 W/kg	5,600 - 6,800 W/kg	3,600 W/kg

Images not to scale.

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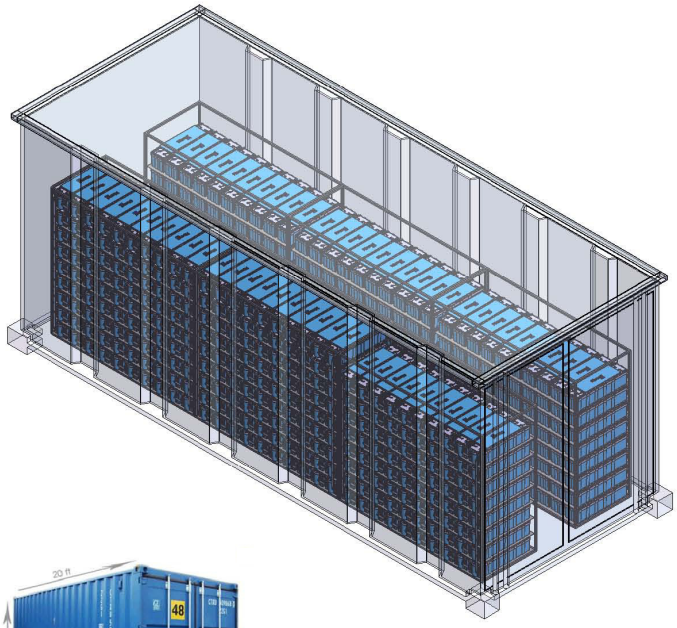
ULTRACAPACITORS

GRID STORAGE APPLICATION BRIEF



Standard 20' container holds
1MW/60 seconds of energy storage

1MW • 60 SECONDS • 1,000,000 CHARGE-DISCHARGE CYCLES ENERGY STORAGE

As renewable energy sources grow in use and the percentage of grid power met by renewables increases grid stability becomes an increasingly important issue. The variability in wind and solar output creates instability on the grid. This variability also results in poor utilization of these resources by 30-50%.

Maxwell ultracapacitors can help combat these challenges by providing a few seconds of reactive power in a cost effective and smaller package size. The long life, high power and superior charge/discharge cycling of ultracapacitors make them the ideal energy storage for firming the output of renewable installations. With Maxwell ultrapacitors energy storage, it is easy to design scalable systems with lifetimes over a million charge/discharge cycles at 100% depth of discharge.

Renewables ride-through and firming, Hybrid Energy Storage Systems component

Applications
- VARs support
- Regulation up, regulation down
- Renewable energy firming – wind or solar smoothing
- Frequency regulation

Maxwell Technologies Over 11 GW total power installed

Scaleable energy storage 560V/1MW/60 seconds
- 20 foot container
- Add your power electronics and controls

Green Technology
- Lead free
- No toxic materials

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ULTRACAPACITORS

GRID STORAGE APPLICATION BRIEF

Specifications

	48 V Module	56 V Module
Capacitance	165 F	130 F
Voltage	48 V	56 V
ESR, DC	6.3 mohm	8.1 mohm
Leakage Current	5.2 mA	120 mA
E_{max}	3.9 Wh/kg	3.1 Wh/kg
P_{max}	6,800 W/kg	5,400 W/kg

1 MW / 60 Sec. / 1 Million Cycle Module Specifications

Configuration	646 x 48 V Modules	500 x 56 V Modules
Capacitance	372 F	650 F
Voltage	740 V	560 V
Floor Space*	106 ft^2	89 ft^2
Peak Power**	23 MW	23 MW
Average Power**	1 MW	1 MW

* 6′ height
** 75% Depth of discharge
Images not to scale

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FEATURES AND BENEFITS

- Compact, rugged, fully enclosed splash proof design
- Highest power performance available
- Individually balanced cells
- Over 1,000,000 duty cycles
- Ultra-low internal resistance
- Voltage & temperature sensor output included

TYPICAL APPLICATIONS

- Automotive
- Industrial
- Telecommunications
- Bus, Train
- Uninterruptible Power Supplies (UPS)

PRODUCT SPECIFICATIONS

ELECTRICAL	BMOD0083	BMOD0165
Rated Capacitance[1]	83 F	165 F
Minimum Capacitance, initial[1]	83 F	165 F
Maximum ESR $_{DC,}$ initial[1]	10 mΩ	6.3 mΩ
Rated Voltage	48 V	48 V
Absolute Maximum Voltage[14]	51 V	51 V
Maximum Continuous Current (ΔT = 15°C)[2]	61 A_{RMS}	77 A_{RMS}
Maximum Continuous Current (ΔT = 40°C)[2]	100 A_{RMS}	130 A_{RMS}
Maximum Peak Current, 1 second (non repetitive)[3]	1,100 A	1,900 A
Leakage Current, maximum (B01 Suffix - VMS 2.0)[4]	3.0 mA	5.2 mA
Maximum Series Voltage	750 V	750 V
TEMPERATURE		
Operating Temperature (Ambient temperature)		
Minimum	-40°C	-40°C
Maximum	65°C	65°C
Storage Temperature (Stored uncharged)		
Minimum	-40°C	-40°C
Maximum	70°C	70°C

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PRODUCT SPECIFICATIONS (Cont'd)

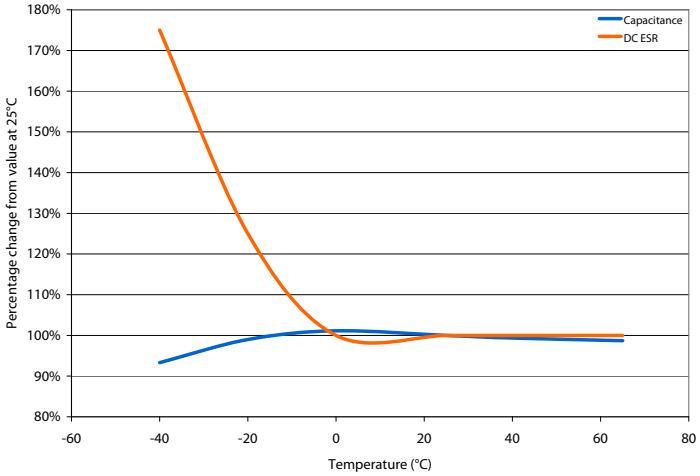
PHYSICAL	BMOD0083	BMOD0165
Mass, typical	10.3 kg	13.5 kg
Power Terminals	M8/M10	M8/M10
Recommended Torque - Terminal	20/30 Nm	20/30 Nm
Vibration Specification	SAE J2380	SAE J2380
Shock Specification	SAE J2464	SAE J2464
Environmental Protection	IP65	IP65
Cooling	Natural Convection	Natural Convection
MONITORING / CELL VOLTAGE MANAGEMENT		
Internal Temperature Sensor	NTC Thermistor	NTC Thermistor
Temperature Interface	Analog	Analog
Cell Voltage Monitoring	Overvoltage Alarm	Overvoltage Alarm
Connector	Deutsch DTM	Deutsch DTM
Cell Voltage Management	VMS 2.0	VMS 2.0
POWER & ENERGY		
Usable Specific Power, P_d [5]	2,700 W/kg	3,300 W/kg
Impedance Match Specific Power, P_{max} [6]	5,600 W/kg	6,800 W/kg
Specific Energy, E_{max} [7]	2.6 Wh/kg	3.9 Wh/kg
Stored Energy[8]	26.6 Wh	52.8 Wh
LIFE		
High Temperature[1] (at Rated Voltage & Maximum Operating Temperature)	1,500 hours	1,500 hours
Capacitance Change (% decrease from minimum initial value)	20%	20%
ESR Change (% increase from maximum initial value)	100%	100%
Room Temperature[1] (at Rated Voltage & 25°C)	10 years	10 years
Capacitance Change (% decrease from minimum initial value)	20%	20%
ESR Change (% increase from maximum initial value)	100%	100%

PRODUCT SPECIFICATIONS (Cont'd)	BMOD0083	BMOD0165
Cycle Life[1,9]	1,000,000 cycles	1,000,000 cycles
Capacitance Change (% decrease from minimum initial value)	20%	20%
ESR Change (% increase from maximum initial value)	100%	100%
Test Current	100 A	100 A
Shelf Life[1,10] (Stored uncharged up to a maximum storage temperature)	2 years	2 years
SAFETY		
Short Circuit Current, typical (Current possible with short circuit from rated voltage. Do not use as an operating current.)	4,800 A	7,600 A
Factory High-Pot Test[13]	2,500 V DC	2,500 V DC
Certifications	RoHS	RoHS UL810a (150 Volts)

TYPICAL CHARACTERISTICS

THERMAL CHARACTERISTICS		
Thermal Resistance ($R_{cm,}$ One Cell Case to Module Case), typical[2]	1°C/W	1°C/W
Thermal Resistance ($R_{ma,}$ Module Case to Ambient), typical	0.30°C/W	0.25°C/W
Thermal Resistance ($R_{ca,}$ All Cell Cases to Ambient), typical	0.40°C/W	0.40°C/W
Thermal Capacitance (C_{th}), typical [2]	7,675 J/°C	12,715 J/°C

ESR AND CAPACITANCE VS TEMPERATURE



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NOTES

1. Capacitance and ESR_{DC} measured at 25°C per Document Number 1007239 available at www.maxwell.com.
2. Per Maxwell Document 1007239 available at www.maxwell.com.
3. Maximum Peak current (1 sec) = $\frac{½\ CV}{C \times ESR_{DC} + 1}$
4. After 72 hours at 25°C and rated voltage. Initial leakage current can be higher.
5. Per IEC 62391-2, $P_d = \frac{0.12V^2}{ESR_{DC} \times mass}$
6. $P_{max} = \frac{V^2}{4 \times ESR_{DC} \times mass}$
7. $E_{max} = \frac{½\ CV^2}{3{,}600 \times mass}$
8. $E_{stored} = \frac{½\ CV^2}{3{,}600}$
9. Cycle per Document Number 1007239 available at www.maxwell.com.
10. No more than 10% decrease in capacitance from minimum initial capacitance or 50% increase in ESR from maximum initial ESR.
11. Tested at 1 kV DC.
12. For a given application, sufficient cooling must be provided to keep cell case temperatures below 65°. See R_{th}.
13. Duration = 60 seconds. Not intended as an operating parameter.
14. Absolute maximum voltage non repeated, not to exceed 1 second.

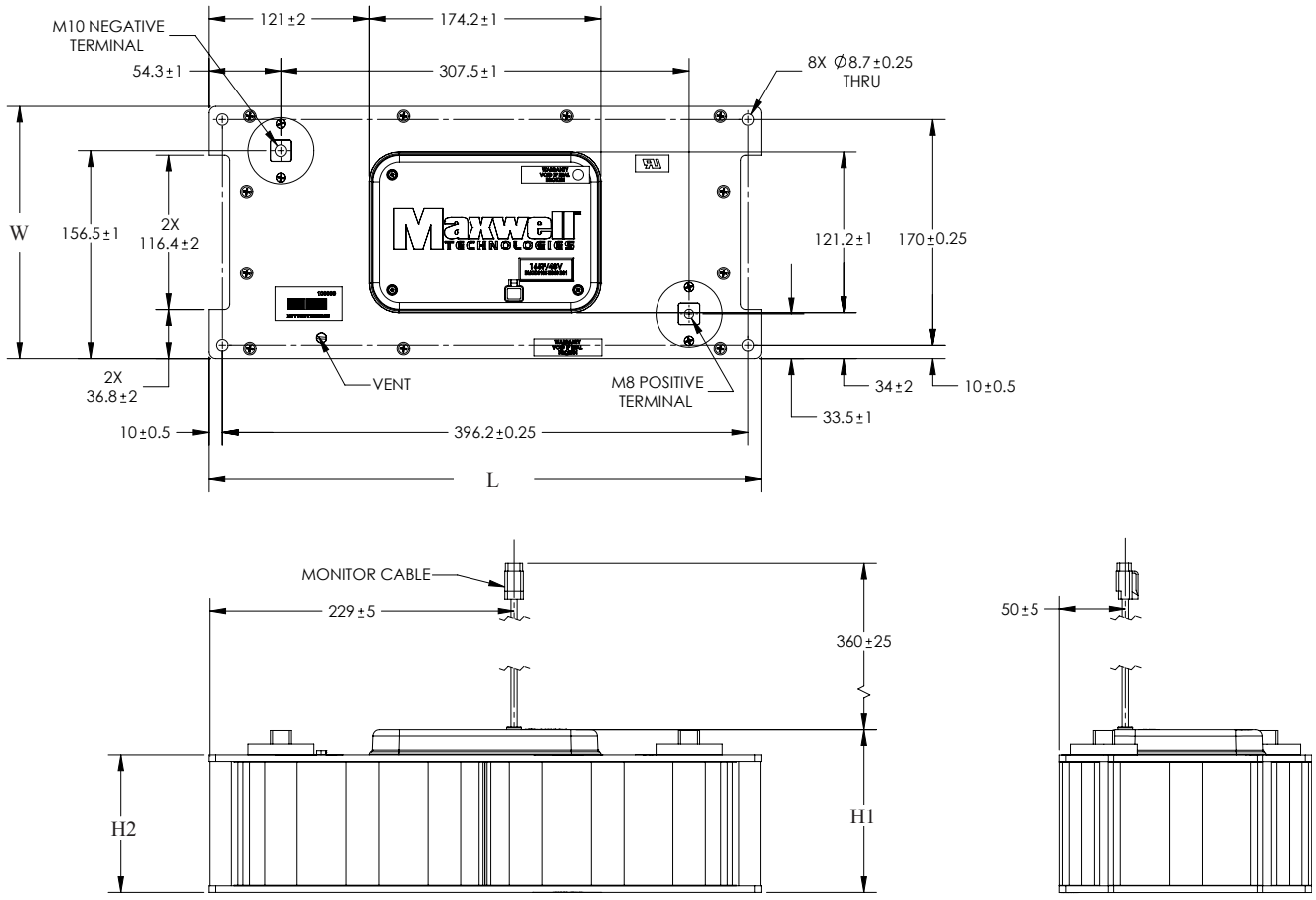
MOUNTING RECOMMENDATIONS

Please refer to the user manual for installation recommendations.

MARKINGS

Products are marked with the following information: Rated capacitance, rated voltage, product number, name of manufacturer, positive and negative terminal, warning marking, serial number.

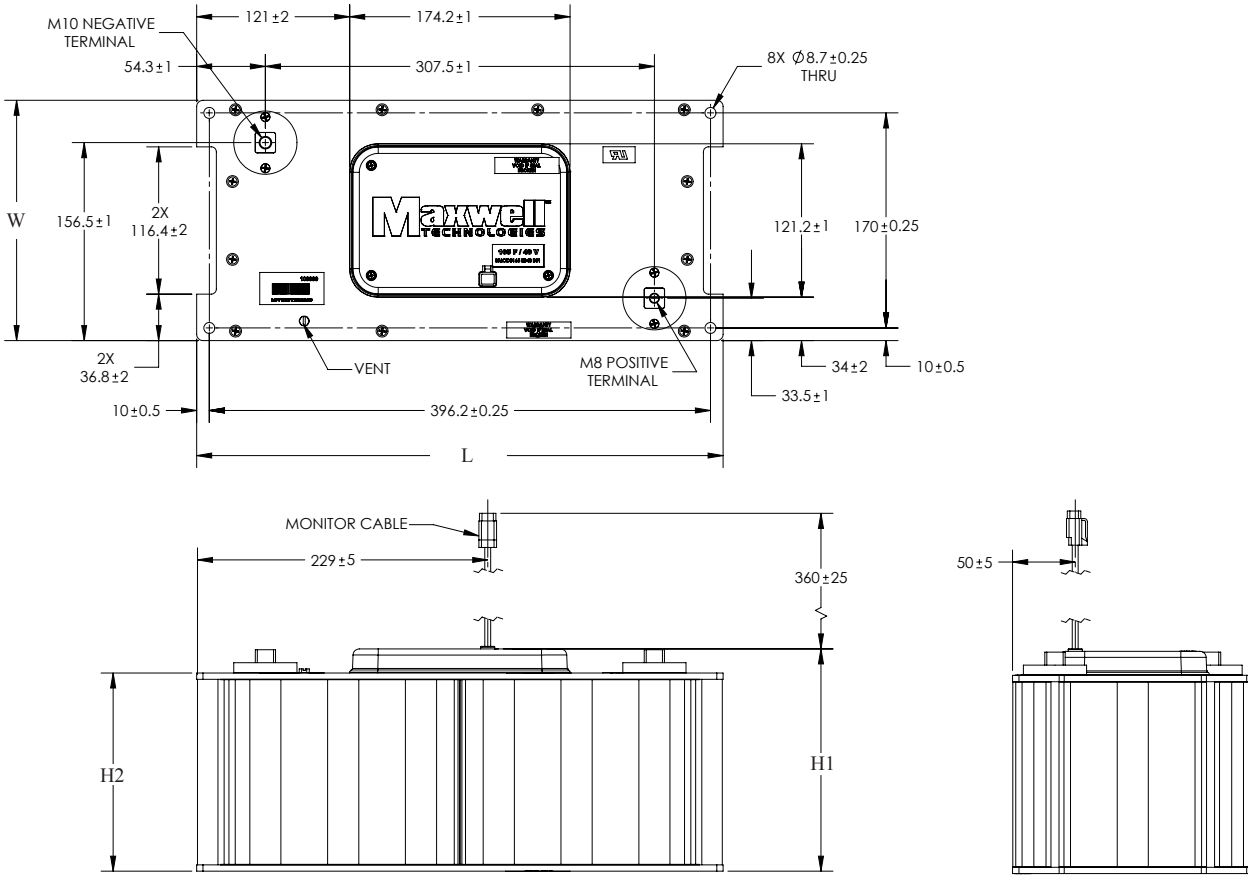
BMOD0083 P048 B01



Part Description	Dimensions (mm)				Package Quantity
	L (max)	W (max)	H1 (max)	H2 (max)	
BMOD0083 P048 B01	418	191	126	106	1

Product dimensions are for reference only unless otherwise identified. Product dimensions and specifications may change without notice. Please contact Maxwell Technologies directly for any technical specifications critical to application.

BMOD0165 P048 B01



Part Description	Dimensions (mm)				Package Quantity
	L (max)	W (max)	H1 (max)	H2 (max)	
BMOD0165 P048 B01	418	194	179	157	1

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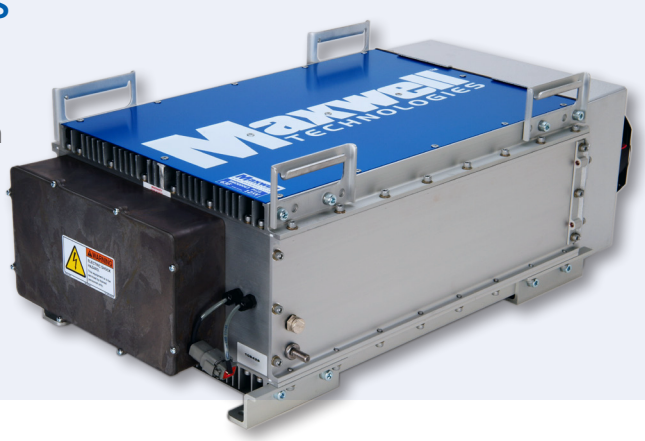
DATASHEET 125V HEAVY TRANSPORTATION MODULES

FEATURES AND BENEFITS

- CAN bus digital monitoring and communications
- Highest power performance available
- Over 1,000,000 duty cycles
- Temperature and voltage monitoring
- Ultra-low resistance

TYPICAL APPLICATIONS

- Buses
- Electric trains and trolleys
- Heavy duty transportation
- Cranes, RTGS
- Utility vehicles
- Mining equipment



PRODUCT SPECIFICATIONS

ELECTRICAL	BMOD0063 P125 B04/B08
Rated Capacitance[1]	63 F
Minimum Capacitance, initial[1]	63 F
Maximum $ESR_{DC,}$ initial[1]	18 mΩ
Rated Voltage	125 V
Absolute Maximum Voltage[15]	136 V
Maximum Continuous Current (ΔT = 15°C)[2]	140 A_{RMS}
Maximum Continuous Current (ΔT = 40°C)[2]	240 A_{RMS}
Maximum Peak Current, 1 second (non repetitive)[3]	1,800 A
Leakage Current, maximum (VMS 2.0)[4]	10 mA
Maximum Series Voltage	1,500 V
TEMPERATURE	
Operating Temperature (Ambient temperature)	
Minimum	-40°C
Maximum	65°C
Storage Temperature (Stored uncharged)	
Minimum	-40°C
Maximum	70°C

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PRODUCT SPECIFICATIONS (Cont'd)

PHYSICAL	BMOD0063 P125 B04/B08
Mass, typical[13]	60.5 kg
Power Terminals	Radsok
Recommended Torque - Terminal	N/A
Vibration Specification	ISO16750-3 Table 14
Shock Specification	SAE J2464
Environmental Protection	IP65
Cooling	Forced Air
MONITORING / CELL VOLTAGE MANAGEMENT	
Temperature Interface	Serial Data (CAN)
Cell Voltage Monitoring	Group Voltage (CAN)
Connector	Deutsch DTM
Cell Voltage Management	VMS 2.0
POWER & ENERGY	
Usable Specific Power, P_d[5]	1,700 W/kg
Impedance Match Specific Power, P_{max}[6]	3,600 W/kg
Specific Energy, E_{max}[7]	2.3 Wh/kg
Stored Energy[8]	136.7 Wh
LIFE	
High Temperature[1] (at Rated Voltage & Maximum Operating Temperature)	1,500 hours
Capacitance Change (% decrease from minimum initial value)	20%
ESR Change (% increase from maximum initial value)	100%
Room Temperature[1] (at Rated Voltage & 25°C)	10 years
Capacitance Change (% decrease from minimum initial value)	20%
ESR Change (% increase from maximum initial value)	100%
Cycle Life[1,9]	1,000,000 cycles
Capacitance Change (% decrease from minimum initial value)	20%
ESR Change (% increase from maximum initial value)	100%
Test Current	100 A
Shelf Life[1,10] (Stored uncharged up to a maximum storage temperature)	2 years

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PRODUCT SPECIFICATIONS (Cont'd)

BMOD0063 P125 B04/B08

SAFETY

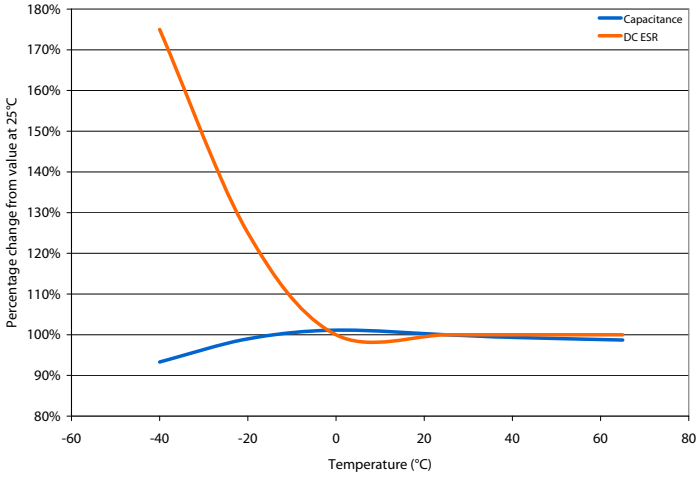
Short Circuit Current, typical (Current possible with short circuit from rated voltage. Do not use as an operating current.)	6,900 A
Factory High-Pot Test[14]	4,000 V DC
Certifications	RoHS eMark 72/245/EEC (B08 only) UN10.03 (B08 only)

TYPICAL CHARACTERISTICS

THERMAL CHARACTERISTICS

Thermal Resistance ($R_{ma,}$ Modulel Case to Ambient), typical	0.01°C/W
Thermal Resistance ($R_{ca,}$ All Cell Cases to Ambient), typical	0.04°C/W
Thermal Capacitance (C_{th}), typical [2]	33,370 J/°C

ESR AND CAPACITANCE VS TEMPERATURE



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NOTES

1. Capacitance and ESR_{DC} measured at 25°C per Document Number 1007239 available at www.maxwell.com.
2. Per Maxwell Document 1007239 available at www.maxwell.com.
3. Maximum Peak current (1 sec) = $\frac{½\ CV}{C \times ESR_{DC} + 1}$
4. After 72 hours at 25°C and rated voltage. Initial leakage current can be higher.
5. Per IEC 62391-2, $P_d = \frac{0.12V^2}{ESR_{DC} \times mass}$
6. $P_{max} = \frac{V^2}{4 \times ESR_{DC} \times mass}$
7. $E_{max} = \frac{½\ CV^2}{3{,}600 \times mass}$
8. $E_{stored} = \frac{½\ CV^2}{3{,}600}$
9. Cycle per Document Number 1007239 available at www.maxwell.com.
10. No more than 10% decrease in capacitance from minimum initial capacitance or 50% increase in ESR from maximum initial ESR.
11. Tested at 1 kV DC.
12. For a given application, sufficient cooling must be provided to keep cell case temperatures below 65°. See R_{th}.
13. Without fan. With fan, mass is 63.4 kg.
14. Duration = 60 seconds. Not intended as an operating parameter.
15. Absolute maximum voltage non repeated, not to exceed 1 second.

MOUNTING RECOMMENDATIONS

Please refer to the user manual for installation recommendations.

MARKINGS

Products are marked with the following information: Rated capacitance, rated voltage, product number, name of manufacturer, positive and negative terminal, warning marking, serial number.

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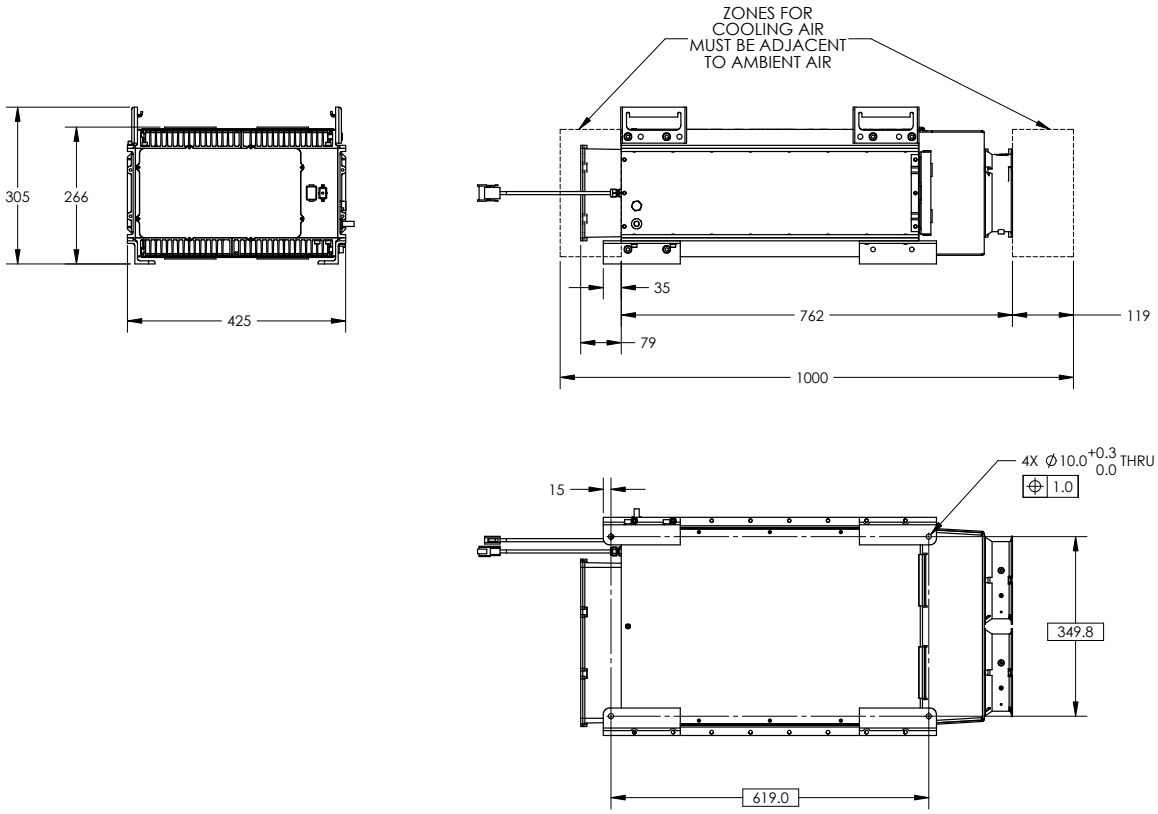
BMOD0063 P125 Bxx



Part Description	Dimensions (mm) L (±0.5mm)	W (±0.2mm)	H (±0.7mm)	Package Quantity
BMOD0063 P125 B04/08	619	425	265	1

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ORDERING INFORMATION

Base Module

109120B	BMOD0063 P125 B04 63F/125V Module with CAN Comm.
109024B	BMOD0063 P125 B08 63F/125V e-mark Module with CAN Comm.

Power Connection Kit

109131	Power Connection Kit, 90DEG
109132	Power Connection Kit, STRAIGHT

Communication Kit

109133	CAN SIGNAL, Deutsch

Fan Kit

109134	FAN KIT, 24V Standard
129036	FAN KIT, 24V, E-Mark

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